Stability of fluid flow through deformable channels and tubes: an overview

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This presentation will provide a systematic overview of the study of instabilities in flow past deformable solid surfaces, with particular emphasis on internal flows through tubes and channels. The subject is certainly more than five decades old, and arguably began with Kramer's pioneering experiments on drag reduction by compliant surfaces. This was immediately followed by the theoretical studies of Benjamin and Landhal in the early 1960s. Most earlier theoretical studies were focused on boundary layer stability, and had used simplistic wall models comprised of spring-backed plates. There was a resurgence in the field since the mid-1980s, and more attention was focused on internal flows through deformable tubes and channels. The wall deformation was described by both phenomenological spring-backed plate models as well as by continuum linear viscoelastic solid models. All these studies predict several types of instabilities in flow past deformable surfaces. This presentation will attempt to place all the theoretical results in perspective, and try to classify the instabilities predicted by various studies. Recent studies have also emphasized the importance of using a frame-invariant constitutive model, such as the neo-Hookean model, for the solid deformation. Until recently, however, the field has been dominated by theoretical and numerical studies, with very little experimental observations to corroborate the theoretical predictions. Recent experiments in flow through deformable tubes and channels indeed show instability at Reynolds number much lower than their rigid counterparts, and the experimental observations are in qualitative agreement with some of the theoretical predictions. There have also been a few studies on the non-linear aspects of the instability using the weakly non-linear formulation to determine the nature of the bifurcation at the linear instability, and this presentation will briefly touch upon these as well.

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